

GETTING ORGANIZED

There thus emerged the idea of the ether as a foam.

Denis Weaire (1996)

Is there a way in which the universe may have organized itself?

John Brockman (1997)

A theory of a whole universe, if it is to be consistent with what we know of quantum theory and relativity, must be a theory of a complex, self-organized universe.

Lee Smolin (1997)

In the end, we want a theory that works on all scales—a theory that gives us both particle physics and cosmology.

Shing-Tung Yau (2010)

Things are quiet in the office as I settle into chaos. It's another concept he may need to know. Poincaré invents its theory in the 1800s. It takes a while to come of age. Then computers give it traction; calculating chaos needs a *CPU*.

So, what is it? Some may imagine a teenager's room. But scientists mean something more specific. They have in mind the way a twitch can turn into a transformation. It's called the butterfly effect. He must have heard of how a butterfly that flutters by in Rio triggers a tornado in Texas.

My reason for inflicting chaos on him—if he will listen long enough—begins with Brockman's question. It leads me to a book called *Order out of Chaos*, which teaches me that chaos is the evil twin of self-organization. It works like this: There are two ways to fix a traffic jam in Turkey. One is dispatchers who send cops to sort out traffic where they're needed, which is everywhere; it doesn't work. The other way relies on drivers. Every Turkish driver knows a three-lane highway under pressure has no less than five point seven lanes. As if by magic traffic sorts itself with no police direction. Order comes from chaos car by car. How? Well, the tendency to organize is built into the pieces of the mess. But he's never been to Istanbul. Instead I find an article on how pedestrians make order out of crowds; he's seen a lot of that.

Of course it isn't limited to wheels and heels. Weather is the classic case in point. In fact it's a forecaster, Edward Lorenz, who finds the butterfly effect. By chance he sees that tiny changes in the data fed to a computer—today's temperature in Memphis, for example—yield wild swings in the forecast for New York next week.

What I need is an example of how the chaos of a zillion tiny pieces can lead something large to organize itself. Of how simple pieces run by rules give rise to structure that's not present in the rules. Lorenz gives me the idea: It's Katrina. Consider, I will ask him, the Atlantic surface in, say, August or September. The sun is tracking north of the Equator. Up close the ocean surface is a simple system: molecules of water mix with molecules of air. The rules for what they do in millions or in billions are well understood. They are boring. But with many more and photons added, something else is going on.

Sol is a thermonuclear reactor. It turns more than a million tons of matter into energy each second. Ninety million miles away Earth picks up the proceeds of about five pounds—equal, Einstein says, to a few 10-megaton H-bombs. The horrors of a thousand Hiroshimas every second are avoided by the fact that this gets spread around. But those molecules bring some of it together! Here is how: Solar photons end up in the surface water. It gets warm. Some evaporates. Water vapor makes air lighter. So it tries to rise. At first there is a standoff over which half acre gets to go first. In the end some bit of it—maybe a million tons—will win. As it quits the surface it sucks moist air in from all around. The Earth's rotation gives the rising mass a spin. It has organized itself into a monster. The questions now are: How big will it get to be? Which way will it go? And what's its name? If enough of the sea surface is warm enough—one degree makes a big difference—vast amounts of moist air rise. Soon ten billion tons of air—much more if it's a big one—are spinning up and on the move.

Of course the universe is much more complex than a hurricane. But I'm ready if he raises this. Next time you shave, I'll say, look closer; you are a self-organizing system. You think your body lasts a lifetime. But the only thing that lasts is rules that govern atoms as they pose in a group photo. It's all just atoms passing through. The hydrogen and oxygen of water in the body have a half-life of ten days. That is, in ten days the body excretes half the molecules of water and replaces them with water taken in. Calcium turns over slower but it's mostly in a tug of war, a balance between breaking down and building up of bone. The entire body is a complex flow of atoms moving to and through us and then back into the world. Weiner says that 'over the span of seven years or so, almost every atom in your body has been let go and replaced.' Is it then far-fetched to think of the universe as a self-organizing system? Of course a hurricane is different. It exists *in* an outside environment. It is as captive as a candle flame to its location. The universe is in no environment. If it does organize itself, the way it does must lie inside.

One thing I learn seems extra useful: Self-organization is said to be emergent. This means that all the system's properties *emerge* from the complexity that follows its initial state. They emerge without outside interference or direction—the

physics jargon is with no fine-tuning. So what is it that physics finds emerging that might be our universe? And what does it emerge from?

Well, the leading candidate for what emerges is *Spin Foam*. Or rather that's the name for a Spin Network that evolves in time. It is sure to piss him off. It's back to the world of Penrose, froot-loops, LQG. The Spin Foam is the whole thing in 4-D. Well, this is the tricky bit, but it's the entire point: The Spin Foam isn't *in* space and time, it *is* space and time. Of course there's more to it than that. But a Spin Foam is a set of rules. They are simpler than the rules of poker. Variations on the rules make different Spin Foams and poker games. Physicists are seeking a Spin Foam that works as time and space. *That's* what must emerge.

And what does it emerge *from*? Well, it emerges from a Spin Network. Which emerges from a set of rules. Which seems to beg another vexed question: Whence emerge the rules?